Buffer Zone (BZ)

Practice Description

A buffer zone is a strip of plants adjacent to land-disturbing sites or bordering streams, lakes, and wetlands which provides streambank stability, reduces scour erosion, reduces storm runoff velocities and filters sediment in stormwater. This practice applies on construction sites and other disturbed areas that can support vegetation and can be particularly effective on floodplains, next to wetlands, along streambanks and on steep, unstable slopes.

Planning Considerations

The width and plant composition of a buffer zone will determine its effectiveness.

There is no ideal width and plant community for buffer zones. A buffer zone 50 feet wide with desirable vegetation may provide significant protection of a perennial stream, water body or wetland. Adjustments can be made to account for the purpose(s) of the buffer and landscape characteristics.

Three zones are typically recognized in the buffer area. If planned to be 45 to 55 feet wide, the recommended width and plant categories are described in the following listings:

- Zone 1: the first 15 to 20 feet nearest the stream. Cover is close growing trees (commonly 6 to 10 feet apart).
- Zone 2: the next 10 to 15 feet. Cover is trees or trees and shrubs.
- Zone 3: the next 20 feet. Cover is grass or dense groundcover.

Note: All widths are for one side of the stream only and are measured from top of stream bank.

Existing vegetation should be considered for retention, especially hardwoods that are in Zones 1 and 2.

Buffer Zone 3 may be established with a grass planting or with close-growing groundcover that will provide dense cover to filter sediment. Where topography accommodates sheet flow from the adjacent landscape, Zone 3 should be retained or developed as a Filter Strip.

Necessary site preparation and planting for establishing new buffers should be done at a time and manner to insure survival and growth of selected species.

Buffer zones may become part of the overall landscape of the project.

The layout and density of the buffer should complement natural features and mimic natural riparian forests.

Design Criteria

Installation (Preservation)

Evaluate vegetation and landscape features in proposed buffer zone to determine potential for existing plant community to maintain streambank stability, prevent sheet, rill and scour erosion, reduce stormwater velocities and filter sediment.

Dedicate a vegetated zone to effectively minimize streambank and shoreline erosion, prevent sheet, rill and scour erosion in the buffer zone and remove sediment from sheet flow from the disturbed area. Initially estimate a width of 50 feet wide adjacent to the stream (each side), water body or wetland. Adjust the width to account for slope of the land adjacent to the stream and the purposes of the buffer. If the buffer is planned to trap sediment in sheet flow the width should be increased 2 feet for every 1% slope measured along a line perpendicular to the streambank and immediately downslope of the disturbed area. If the buffer is not planned to trap sediment and only bank stabilization is the purpose of the buffer only Zones 1 and 2 are required and the adjustment for slope of the adjacent land is not essential.

Installation (Plantings)

Width and Zone Requirements

Use guidance under Installation (Preservation) to determine width and zone requirements.

Site Preparation

Plan appropriate site preparation to provide a suitable planting medium for grass, or trees and shrubs.

Plan to install sediment and erosion control measures such as silt fence and diversions if zones are graded before seedbed preparation.

If significant compaction exists, plan for chiseling or subsoiling.

For Zone 3 plantings, clear area of clods, rocks, etc. that would interfere with seedbed preparation; smooth the area, to encourage sheet flow, before the soil amendments are applied and firm the soil after the soil amendments are applied. Follow guidelines in the Filter Strip practice Design Criteria if Zone 3 is to be used to filter sheet flow from the adjacent construction area.

Soil Amendments (lime and fertilizer)

Plan soil amendments using design criteria for the appropriate category (Permanent Seeding, Tree Planting on Disturbed Areas, and Shrub, Vine and Groundcover Planting). Incorporate amendments to a depth of 4” to 6” with a disk or chisel plow.

Plantings

Plan the vegetation for buffer zones using Design Criteria for Permanent Seeding, Tree Planting on Disturbed Areas, and/or Shrub, Vine and Groundcover Planting. No invasive species shall be used. If trees are planted, at least 2 hardwood species should be used.

Mulching

Plan to mulch shaped areas, and other areas that are bare using the Mulching practice Design Criteria.

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Channel Stabilization (CS)

Practice Description

Channel stabilization is stabilizing a channel, either natural or artificial, in which water flows with a free surface. The purpose of this practice is to establish a non-erosive channel. This practice applies to the stabilization of open channels and existing streams or ditches with drainage areas less than 1 square mile. Methods of channel stabilization include rock riprap lining, concrete lining and grade stabilization structures.

Note: The design of open channel conveyance structures other than Grass Swale is beyond the scope of this edition of the Alabama Handbook and should be done by a qualified design professional and meet applicable state, federal and local regulatory requirements.

Planning Considerations

This practice applies to the improvement or stabilization of open channels and existing streams or ditches with drainage areas less than 1 square mile. Channels with drainage greater than 1 square mile will be designed with appropriate criteria. In all cases, channel stabilization design should be done by a qualified design professional experienced in hydrology and hydraulics. An adequate outlet for the channel must be available for discharge by gravity flow. Construction or other improvements to the channel should not adversely affect the environmental integrity of the area and must not cause significant erosion upstream or flooding and/or sediment deposition downstream.

The alignment and design of channels and stabilization structures shall give careful consideration to the preservation of valuable fish and wildlife habitat and trees of significant value for aesthetic purposes.

Where construction will adversely affect significant fish or wildlife habitat, mitigation measures should be included in the plan. Mitigation measures may include in-stream structures such as pools, riffles, and woody structures, or streamside measures such as trees, shrubs, and other features that enhance wildlife habitat.

Due to the varied nature of these considerations an interdisciplinary team consisting of engineers, hydrologists, and wildlife biologists should prepare the design of streambank protection for each unique channel reach. If instability is occurring over a significant length of stream the team should consider performing a geomorphic analysis of the stream. All local, state and federal laws, especially laws relating to 404 permits should be followed during the design and construction process.

Design Criteria

Realignment

The realignment of channels should be kept to an absolute minimum. Where realignment is unavoidable, the realigned channel should be designed to have a stable grade considering the soil type, vegetation, and new channel length.

Channel Capacity

The design capacity of open channels and stabilization structures should be determined by procedures applicable to the purposes to be served.

Hydraulic Requirements

Manning's formula should be used to determine velocities in channels. The "n" values for use in this formula should be estimated using currently accepted guides along with knowledge and experience regarding the conditions. Acceptable guides can be found in hydrology textbooks.

Channel Cross-Section

The required channel cross section of new or realigned channels is determined by the design capacity, the bed and bank materials, vegetation, and the requirements for maintenance. A minimum depth may be required to provide adequate outlets for subsurface drains and tributary channels. In order to enhance fisheries and wildlife, consider a channel cross section configuration that will ensure concentrated and unobstructed flow during periods of low flow.

Drop Structure

Drop structures are used to reduce or prevent excessive erosion by reduction of velocities in the watercourse or by providing structures that can withstand and reduce the higher velocities. They may be constructed of concrete, rock, masonry, steel, aluminum or non-toxic treated wood.

These structures are constructed where the capability of earth and vegetative measures is exceeded in the safe handling of water at permissible velocities, where excessive grades or overall conditions are encountered or where water is to be lowered structurally from one elevation to another. These structures should generally be planned and installed along with or as part of other erosion control practices. The structures must be designed hydraulically to adequately carry the channel discharge and structurally to withstand loadings imposed by the site conditions.

Channel Stability

All channel construction, improvement and modification should be in accord with a design expected to result in a stable channel which can be maintained.

Characteristics of a stable channel are:

- It neither aggrades nor degrades beyond tolerable limits.
- The channel banks do not erode to the extent that the channel cross section is changed appreciably.
- Excessive sediment bars do not develop.
- Excessive erosion does not occur around culverts, bridges or elsewhere.
- Gullies do not form or enlarge due to the entry of uncontrolled surface flow to the channel.
- The determination of channel stability considers “bankfull” flow.
- Bankfull flow is defined as the flow in the channel which creates a water surface that is at or near normal ground elevation for a significant length of a channel reach. Excessive channel depth created by cutting through high ground, such as might result from realignment of the channel, should not be considered in determinations of bankfull flow.

The design for channels in natural materials shall be considered stable if the check velocity is less than the allowable velocities shown in Table CS-l. The check velocity is defined as the lesser of the bankfull velocity or 10-year frequency peak discharge velocity.

Table CS-1 Allowable Velocities for Various Soil Textures

Soil Texture	Allowable Velocity (ft/sec.)
Sand and Sandy Loam (noncolloidal)	2.5
Silt Loam (also high lime clay)	3.0
Sandy Clay Loam	3.5
Clay Loam	4.0
Stiff Clay, Fine Gravel, Graded Loam to Gravel	5.0
Graded Silt to Cobbles (colloidal)	5.5
Shale, Hardpan and Coarse Gravel	6.0

Channel Linings and Structural Measures

Where channel velocities exceed safe velocities for bare soil, channel linings of rock, concrete or other durable material may be needed. Grade stabilization structures may also be needed.

Use one or more of the following methods to stabilize channels:

Rock Riprap Lining

Rock riprap should be designed to resist displacement when the channel is flowing at the bankfull discharge or the 10-year 24-hour frequency discharge whichever is the lesser. Rock riprap lining should not be used when channel velocities exceed 10 feet per second unless a detailed engineering analysis is performed using appropriate guidelines.

Use Figure CS-1 to determine the stable basic stone weight (d_{100}). Using the d_{100} size as a d_{90}, select a commercially available riprap gradation as classified by the Alabama Department of Transportation, from Table CS-2.

Dumped and machine placed riprap should be installed on slopes flatter than 2 horizontal to 1 vertical. Where riprap is placed by hand the slopes may be steeper. Stone for riprap should consist of field stone or rough unhewn quarry stone of approximately rectangular shape. The stone should be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it should be suitable in all other respects for the purpose intended. The specific gravity of the individual stones should be at least 2.5.

A filter blanket should be placed between the riprap and base material, if needed. A filter blanket is a layer of material placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. A filter blanket should be considered where soils have a high piping potential and/or there is significant seepage of groundwater from the bed or banks.

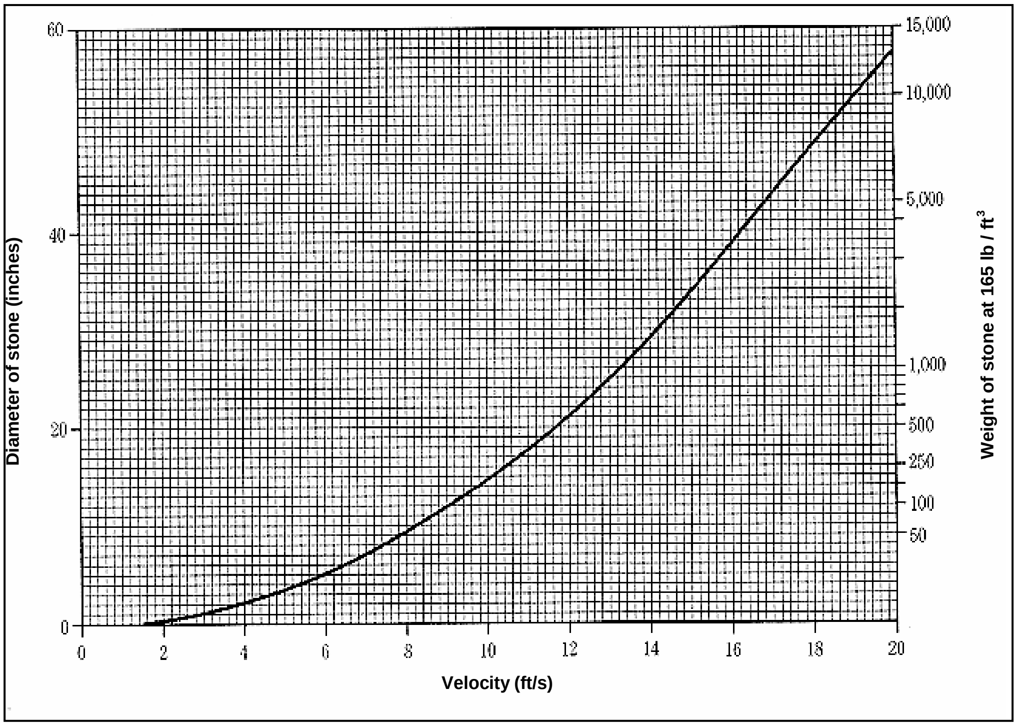

Figure CS-1 Ishbash Curve

1) Determine the design velocity.
2) Use design velocity and Figure CS-1 to determine d_{100} rock size.
3) Use d_{100} from Figure CS-1 as d_{90} to select rock gradation from Table CS-2.

Table CS-2 Commercially Available Riprap Gradations

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

A filter blanket can be of 2 general forms: a gravel layer or a geotextile filter cloth. Gravel filter blankets are to be designed in accordance with the criteria below.

The following relationships must exist:

$$\frac{d_{15}\text{ filter}}{d_{85}\text{ base}} < 5 < \frac{d_{15}\text{ filter}}{d_{15}\text{ base}} < 40$$

$$\frac{d_{50}\text{ filter}}{d_{50}\text{ base}} < 40$$

In these relationships, filter refers to the overlying material and base refers to the underlying material. The relationships must hold between the filter material and the base material and between the riprap and the filter material. In some cases, more than one layer of filter material may be needed. Each layer of filter material should be approximately 6” thick.

Non-woven geotextile filter cloth may be used in place of or in conjunction with gravel filters where appropriate as a separator between rock and soil to prevent migration of soil particles from the subgrade, through the lining material. The geotextile shall be of the strength and durability required for the project to ensure the rock and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

Filter blankets should always be provided where seepage from underground sources threatens the stability of the riprap.

Concrete Lining

Concrete linings should be designed according to currently accepted guides for structural and hydraulic adequacy. They must be designed to carry the required discharge and to withstand the loading imposed by site conditions. Concrete linings are generally used when velocities exceed 10 ft/sec. Erosion at the outlet of concrete lined channels is generally a problem due to the high velocities. Measures should be taken to reduce the velocity and erosion potential at the outlet by use of outlet protection measures (see Outlet Protection practice).

Stream Diversion Channel (SDC)

Practice Description

A stream diversion channel is a temporary practice to convey stream flow in an environmentally safe manner around or through a construction site while a permanent structure or conveyance is being installed in the stream channel.

Planning Considerations

Construction projects often cross and impact live streams creating a potential for excessive sediment delivery into the stream. In cases where in-stream work is unavoidable, a temporary stream diversion channel should be planned. In-stream projects of this nature are subject to the rules and regulations of the U. S. Army Corps of Engineers for in-stream modifications (Clean Water Act Section 404 permit) and if applicable, ADEM CWA Section 401 water quality certification. Temporary stream diversions shall be used only on streams with a drainage area less than 1 square mile (640 acres). Detailed engineering analysis and design should be used for larger drainage areas to ensure a stable diversion channel. For sites with very small drainage areas, the designer may consider temporary blocking and overland pumping of the stream. In order to avoid crossing a live stream, the planner or designer should consider only allowing access for the construction of the permanent structure from the side opposite the stream diversion channel. At locations where access from both sides of the stream is required to construct the permanent structure in the stream channel, a Temporary Stream Crossing (TSC) may be necessary. It is best to locate this crossing either up or downstream of the stream diversion channel.

Vegetation along the existing stream channel should be left undisturbed and protected with effective sediment control practices until such time as the diversion channel is constructed and can safely convey stream flows. Construction equipment should not be allowed to operate in flowing waters and are to be operated and maintained according to the Groundskeeping (GK) practice. Excavated materials should be stockpiled away from the stream and diversion channel and protected to ensure the material does not erode and enter the stream system. The stream diversion channel should be planned and installed in such a manner and time (dry season) that the impact to fisheries and the aquatic environment is minimized. A pictorial representation of a stream diversion channel is shown in Figure SDC-1.

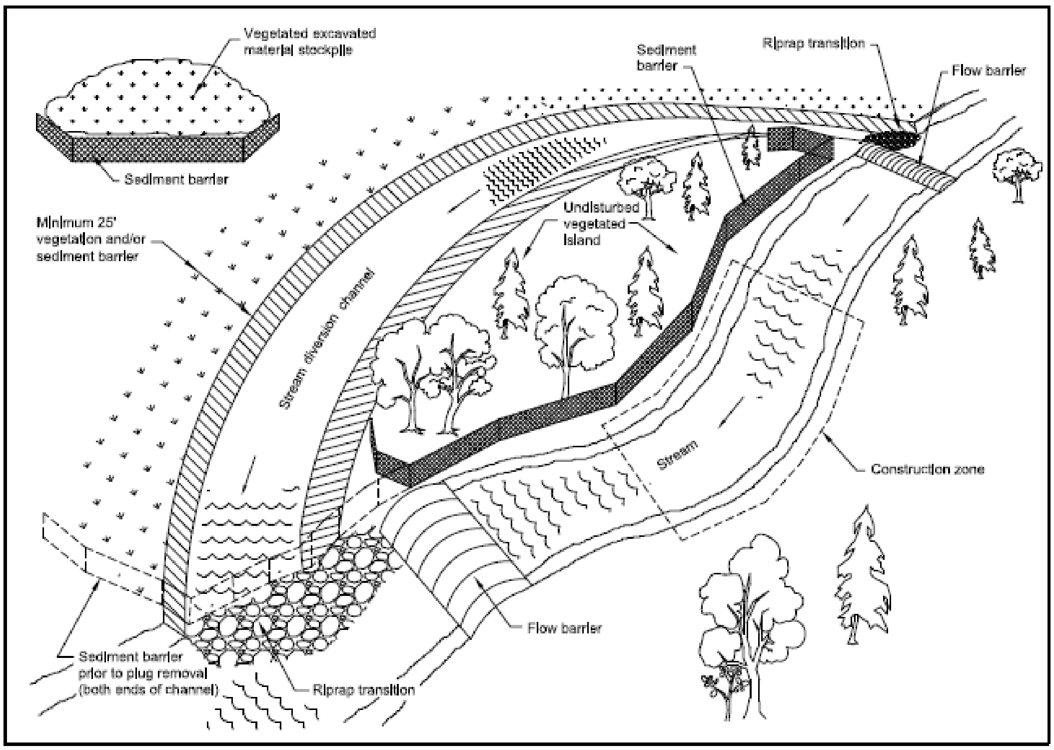

Figure SDC-1 Typical Stream Diversion Channel Layout

Design Criteria

Size

The combination of bottom width, depth, and gradient shall be sufficient to provide the required flow capacity. The minimum bottom width of the stream diversion channel shall be six feet or equal to the bottom width of the existing streambed, whichever is greater. The bottom surface should be shaped or configured to ensure adequate concentrated and unobstructed flow of water during periods of low flow.

Side Slope

Side slopes of the stream diversion channel shall be no steeper than 2 horizontal to 1 vertical (2:1).

Gradient

The diversion bottom grade may be variable, dependent on site conditions, but shall be sufficient to ensure continuous flow of water in the diversion at velocities not exceeding the allowable velocities for the selected channel lining material. The stream diversion channel length should be the same or greater than the length of the stream diverted.

Capacity

The capacity of the stream diversion channel shall be at least bankfull capacity of the existing stream. Consideration should be given to providing greater capacity where construction is expected to extend over several weeks or months.

Channel Lining

The stream diversion channel shall be lined to prevent erosion of the channel and sedimentation in the stream. The lining should be selected based on the velocity at bankfull flow. Use Table SDC-1 for general guidance on the type of lining to be used. Pre-manufactured products like turf reinforcement mats (TRM), cellular blocks, and other similar products shall be designed and installed according to the manufacturer's recommendations.

Table SDC-1 Stream Diversion Channel Linings

Lining Materials	Acceptable Velocity Range
Geotextile fabric, polyethylene film, light weight TRM, block sod	0 – 2.5 fps
Geotextile fabric, heavy weight TRM,	2.5 – 9.0 fps
Class I Riprap and Geotextile, flexible concrete lining	9.0 – 13.0 fps

Riprap linings shall be designed in accordance with the guidance contained in the Channel Stabilization (CS) practice. Class I non-woven geotextile shall be used underneath riprap lining for high velocity applications.

When rolled products like polyethylene film or geotextile fabric are used as a channel lining, the product should be placed so that one width of material will cover the entire channel bottom and slopes while also providing enough material for a minimum 6 inch anchorage at the top of the bank. The upstream end of the material shall be buried at least 2 feet from top of bank to top of bank with additional trench anchorages of at least 1 ft. x 1 ft. at 50 foot intervals. Upstream sections of material shall overlap downstream sections by at least 2 feet and occur at a trench anchorage location. Polyethylene film shall be at least 6 mil thick and be capable of maintaining strength against the effects of ultraviolet light for a period of at least 60 days.

Block sod shall be covered with erosion control netting and staked at minimal 3 ft. x 3 ft. spacing, and staked at the upstream edge of each piece of sod.

Transitions

Additional protection such as riprap may be needed at the entrance and exit portion of the stream diversion channel to ensure velocities do not scour the existing stream bed or bank.

Sequence of Construction

In order to minimize detrimental effects to the environment and the aquatic community, the stream diversion channel should be quickly and carefully installed, well maintained, and removed as soon as possible when the construction area is stable. A sequence of construction should be specified in the contract work. While the sequence of construction should be tailored to the specific site, the general process should be as follows:

- Install sediment barrier at locations alongside stream to intercept runoff from the construction of the stream diversion channel.
- Install sediment barrier around or downstream of stockpile location.
- Maintain vegetation around stream.
- Clear downstream portion of stream diversion channel except for the area of the temporary plug.
- Begin excavation of the stream diversion channel at least 25 ft. from the outlet and maintain this undisturbed plug.
- Stockpile excavated material at designated location and clear additional portions of the stream diversion channel as needed for excavation operations.
- Complete the excavation and leave at least a 25 ft. undisturbed plug at the entrance to the stream diversion channel.
- Dewater the excavated area as needed for installation of the lining and pump the dewatered material to a settling basin before any discharge is allowed.
- Install the lining in diversion channel.

- Excavate the downstream plug and install the transition riprap.
- Adjust sediment barrier locations as needed for stream protection.
- Excavate the upstream plug and install the transition riprap.
- Install an upstream flow barrier, forcing flow into the diversion channel.
- Allow time for aquatic organisms to move or migrate downstream.
- Install a downstream flow barrier if needed.
- Seed and mulch the stockpile and the disturbed area around the stream diversion channel.
- Complete the “in-stream” work.
- Divert flow into the completed “in-stream” conveyance system.
- Place sediment barriers for protection while decommissioning the stream diversion channel.
- Remove channel linings as needed, recycle or properly dispose of the material.
- Place excavated material into diversion channel
- Apply seed and mulch to disturbed areas.

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Streambank Protection (SP)

Practice Description

Streambank protection is the stabilization of the side slopes of a stream. Streambank protection can be vegetative, structural or a combined method (bioengineering) where live plant materials are incorporated into a structure. Vegetative protection is the least costly and the most compatible with natural stream characteristics. Additional protection is required when hydrologic conditions have been greatly altered and stream velocities are excessively high. Streambank protection is often necessary in areas where development has occurred in the upstream watershed and full channel flow occurs several times a year.

Planning Considerations

Since there are several different methods of streambank protection the first step in the design process is a determination of the type protection to be used at the site. Items to consider include:

- Overall condition of the stream within and adjacent to the reach to be stabilized
- Current and future watershed conditions
- Amount of discharge at the site
- Flow velocity at the site
- Sediment load in the stream
- Channel slope
- Controls for bottom scour
- Soil conditions

- Present and anticipated channel roughness
- Compatibility of selected protection with other improvements at the site
- Changes in channel alignment
- Fish and wildlife habitat

Due to the varied nature of these considerations an interdisciplinary team consisting of engineers, hydrologists, and wildlife biologists should prepare the design of streambank protection for each unique channel reach. If instability is occurring over a significant length of stream the team should consider performing a geomorphic analysis of the stream. All local, state and federal laws, especially laws relating to 404 permits should be followed during the design and construction process.

Design Criteria

Velocities

Use vegetation alone with velocities up to 6 ft/sec if the stream bottom is stable. Use structural protection for velocities greater than 6 ft/sec. The design velocity should be the velocity associated with the peak discharge of the design storm for the channel.

Channel Bottom

The channel bottom must be stabilized before installing bank protection. Grade control in the channel bottom may be needed to prevent downcutting (see Channel Stabilization practice).

Permits

All local, state, and federal laws should be complied with during the design and construction of bank protection. If fill is to be placed in wetlands or streams the Army Corps of Engineers should be contacted regarding a 404 permit for the work.

Vegetative Protection

This practice should be used only when velocities are less than 6 ft/sec. The design team should consider the natural zones of a streambank community when selecting vegetation for use in the protection design. Native plant materials should be used for establishment and long term success. No exotic or invasive species should be used.

Aquatic Zone

This area includes the stream bed and is normally submerged at all times (See Figure SP-1). No planting is required in this zone.

Shrub Zone

This zone is on the bank slopes above mean water level and is normally dry except during floods. Plants with high root densities, high root shear and tensile strength, and an ability to transpire water at high rates are recommended for this zone. Willows, silver maples, and poplars are examples of species to use here.

Normally, grasses are not used in this area, but they can be if velocities are low and the grass will not be submerged frequently or for long periods of time.

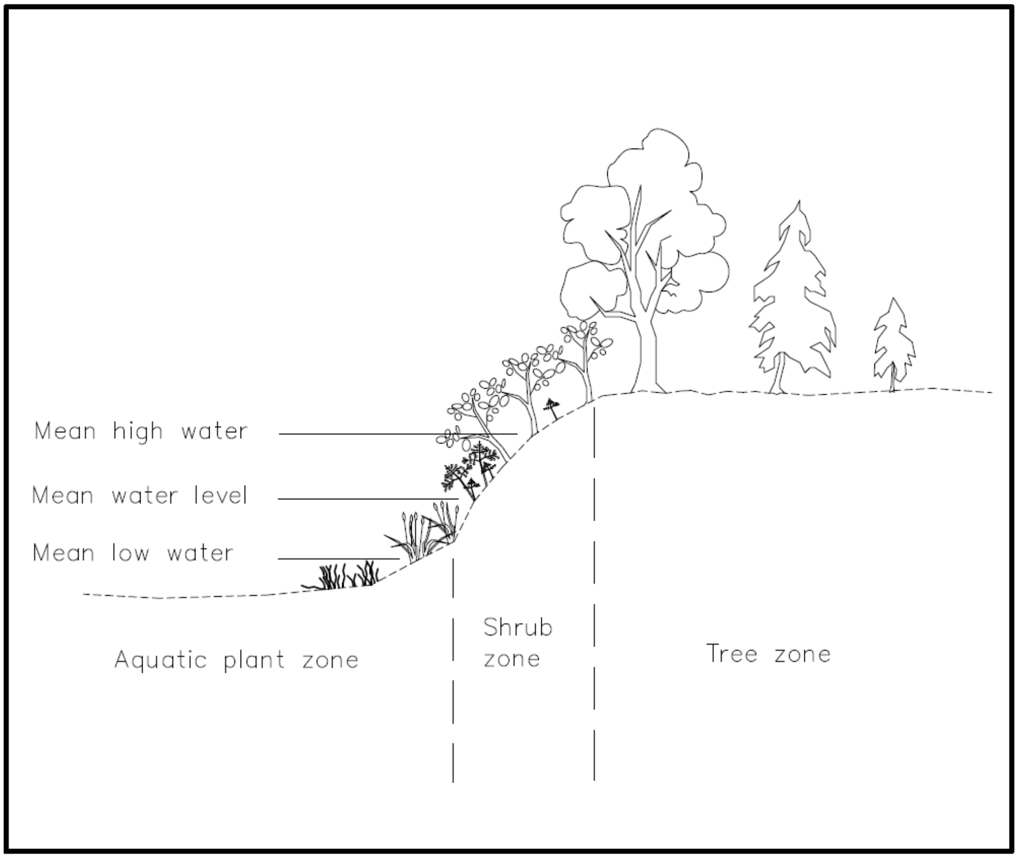

Figure SP-1 Vegetative Zones for Streambank Protection

Tree Zone

This area is at the top of the streambank. Plants in this area usually provide shade for the stream and riparian habitat for wildlife. Upland species should be planted in this location.

Structural Protection

Structural protection is used in areas where velocities exceed 6 feet per second, along channel bends, in areas with highly erodible soils and in areas of steep channel slopes. Common measures are riprap, gabions, fabric-formed revetments and reinforced concrete.

Riprap

This is the most commonly used material for streambank protection. The following criteria should be used when designing riprap bank protection:

- Riprap should be designed to be stable under the design flow conditions using the following procedure:

  1) Determine the design velocity.
  2) Use velocity and figure SP-2 to determine d_{100} rock size.
  3) Use d_{100} from Figure SP-2 as d_{90} to select rock gradation from Table SP-1.

- Streambanks should be sloped at 2:1 or flatter.

- Where needed to prevent movement of soil from the channel bank into the riprap, place a geotextile filter fabric between the soil and riprap. The geotextile shall be of the strength and durability required for the project to ensure the rock and soil base are stable. Generally, the non-woven geotextile should meet the requirements found in ASSHTO M288.

- The toe of the riprap should extend a minimum of 1 foot below the stream channel bottom or anticipated scour depth to prevent failure of the riprap protection.

- The top of the riprap should extend up to the 2-year water surface elevation as a minimum unless it is determined that a lesser height in combination with vegetative measures will provide the needed protection. The remainder of the bank above the riprap can be vegetated.

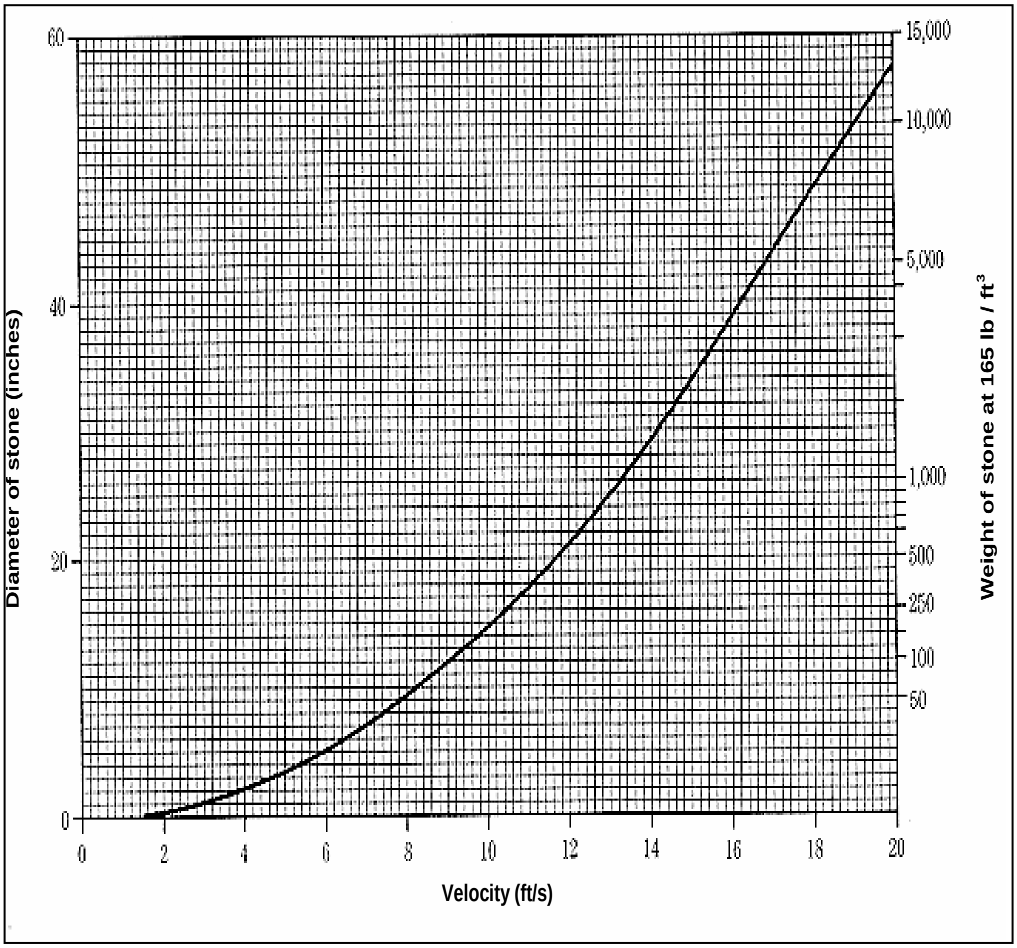

Figure SP-2 Isbash Curve

Table SP-1 Graded Riprap

Class	Weight (lbs.)					
	d_{10}	d_{15}	d_{25}	d_{50}	d_{75}	d_{90}
1	10	-	-	50	-	100
2	10	-	-	80	-	200
3	-	25	-	200	-	500
4	-	-	50	500	1000	-
5	-	-	200	1000	-	2000

Gabions

These rock-filled wire baskets are very labor intensive to construct, but they are semi-flexible and permeable. Gabions should be designed and constructed according to manufacturer's guidelines and recommendations. They should be filled with durable rock. If needed, a filter fabric can be used between the gabions and the soil subgrade. Fabric will be selected from the table for geotextiles shown above.

Fabric-Formed Revetments

These are manufactured, large, quilted envelopes that can be sewn or zipped together at the site to form continuous coverage of the area to be protected. Once the fabric is in place, it is pumped full of grout to form a solid, hard and semi-impervious cover. Revetments should be designed and installed according to manufacturer's recommendations.

Reinforced Concrete

A qualified design professional using sound and accepted engineering procedures should design this protection method. The design should include a solid foundation for the retaining wall and a method of draining excess water from behind the wall.

All structural protection methods should begin and end along stable reaches of the stream.

Combined Methods of Protection

Combinations of vegetative and structural protection can be used in any area where a structural measure would be used. Common measures include cellular matrix confinement systems, grid pavers, and bioengineering techniques. As with structural measures all combined methods should begin and end along stable reaches of the stream.

Cellular Confinement Matrices

These are commercially available products made of heavy-duty polyethylene formed into a honeycomb type matrix. The product is flexible to conform to surface irregularities. The combs may be filled with soil, sand, gravel or cement. Where soil is used to fill the combs vegetation may also be established. These systems should be designed and installed according to manufacturer's recommendations.

Grid Pavers

These are modular concrete units with interspaced voids. They are used to armor the bank and provide an area for vegetation as well. Pavers come in a variety of shapes and sizes with various anchoring methods. They should be designed and installed according to manufacturer's recommendations.

Soil Bioengineering

This method uses live, woody vegetative cuttings to increase slope stability. It can either be a woody vegetation system alone or woody vegetation combined with simple inert structures. It is especially useful in areas with minimal access or environmentally sensitive areas. Following are some general requirements for this method:

Plant Species

Use native species that root easily such as willow and are suitable for the intended use and adapted to site conditions. Plants are usually harvested from a nearby local area.

Cutting Size

Normally ½” to 2” in diameter and from 2 to 6 feet long (length will depend on project requirements).

Harvesting

Cut plant materials at a blunt angle, 8” to 10” from the ground, leaving enough trunk so that cut plants will regrow.

Transportation and Handling

Bundle cuttings together on harvest site, removing side branches. Keep material moist. Handle carefully during loading and unloading to prevent damage. Cover to protect cuttings from drying out.

Installation Timing

Deliver to construction site within 8 hours of harvest and install immediately, especially when temperatures are above 50º F. Store up to 2 days if cuttings are submerged, “heeled in” moist soil, shaded and protected from wind.

Season

Install during plants’ dormant season, generally late October to March.

Soil

Must be able to support plant growth. Compact backfill to eliminate voids and maintain good branch cutting-to-soil contact.

Woody Protective Vegetation

Live staking, live fascines, brushlayers and branchpacking are soil bioengineering practices that use the stems or branches of living plants as a soil reinforcing and stabilizing material. Eventually the vegetation becomes a major structural component of the bioengineered system.

Live Staking

Live staking is the use of live, rootable vegetative cuttings, inserted and tamped into the ground. As the stakes grow, they create a living root mat that stabilizes the soil. Use live stakes to peg down surface erosion control materials. Most native willow species root rapidly and can be used to repair small earth slips and slumps in wet areas.

To prepare live material, cleanly remove side branches, leaving the bark intact. Use cuttings ½” to 1½” in diameter and 2 to 3 feet long. Cut bottom ends at an angle to insert into soil. Cut top square. Tamp the live stake into the ground at right angles to the slope, starting at any point on the slope face. Buds should point up. Install stakes 2 to 3 feet apart using triangular spacing with from 2 to 4 stakes per square yard. An iron bar can be used to make a pilot hole in firm soil. Drive the stake into the ground with a dead blow hammer (hammer head filled with shot or sand). Four-fifths of the live stake should be underground with soil packed firmly around it after installation. Replace stakes that split during installation.

Live Fascines

Live fascines are long bundles of branch cuttings bound together into sausage-like structures. They should be placed in shallow contour trenches and at an angle on wet slopes to reduce erosion and shallow face sliding. This practice is suited to steep, rocky slopes, where digging is difficult.

To prepare live materials, make cuttings from species such as young willows or shrub dogwoods that root easily and have long, straight branches. Make stakes 2 ½ feet long for cut slopes and 3 feet long for fill slopes. Make bundles of varying lengths from 5 to 30 feet or longer, depending on site conditions and limitations in handling. Use untreated twine for bundling. Completed bundles should be 6” to 8” in diameter. Orient growing tips in the same direction. Stagger cuttings so that root ends are evenly distributed throughout the length of the bundle. Install live fascine bundles the same day they are prepared. Prepare dead stakes 2 ½ feet long, untreated 2” by 4” lumber, cut diagonally lengthwise to make 2 stakes. Live stakes will also work. Beginning at the base of the slope, dig a trench on the contour large enough to contain the live fascine. Vary width of trench from 12” to 18”, depending on angle of the slope. Trench depth will be 6” to 8”, depending on size of the bundle. Place the live fascine into the trench. Drive the dead stakes directly through the bundle every 2 to 3 feet. Use extra stakes at connections or bundle overlap. Leave the top of the stakes flush with the bundle. Install live stakes on the downslope side of the bundle between the dead stakes.

Brushlayer

Brushlayering is similar to live fascine systems. Both involve placing live branch cuttings on slopes. However, in brushlayering, the cuttings are oriented at right angles to the slope contour. Use on slopes up to 2:1 in steepness and not over 15 feet in vertical height.

Starting at the toe of the slope, excavate benches horizontally, on the contour, or angled slightly down the slope to aid drainage. Construct benches 2 to 3 feet wide. Slope each bench so that the outside edge is higher than the inside.

Crisscross or overlap live branch cuttings on each bench. Place growing tips toward the outside of the bench. Place backfill on top of the root ends and compact to eliminate air spaces. Growing tips should extend slightly beyond the fill to filter sediment. Soil for backfill can be obtained from excavating the bench above. Space brushlayer rows 3 to 5 feet apart, depending upon the slope angle and stability.

Branchpacking

Branchpacking consists of alternating layers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes (no greater than 4 feet deep or 5 feet wide). Use for earth reinforcement and mass stability of small earthen fill sites.

Make live branch cuttings from ½" to 2" in diameter and long enough to reach from soil at the back of the trench to extend slightly from the front of the rebuilt slope face.

Make wooden stakes 5 to 8 feet long from 2" by 4" lumber or 3" to 4" diameter poles. Start at the lowest point and drive wooden stakes vertically 3 to 4 feet into the ground. Set them 1 to 1½ feet apart. Place a layer of living branches 4" to 6" thick in the bottom of the hole, between the vertical stakes, and at right angles to the slope face. Place live branches in a crisscross arrangement with the growing tips oriented toward the slope face. Some of the root ends of the branches should touch the back of the hole. Follow each layer of branches with a layer of compacted soil to ensure soil contact with the branch cuttings. The final installation should match the existing slope. Branches should protrude only slightly from the rebuilt slope face.

The soil should be moist or moistened to ensure that live branches do not dry out.

Woody Vegetation with Inert Structures

Live cribwalls, vegetated rock gabions and joint plantings are soil bioengineering practices that combine a porous structure with vegetative cuttings. The structures provide immediate erosion, sliding and washout protection. As the vegetation becomes established, the structural elements become less important.

Live Cribwall

A live cribwall consists of a hollow, box-like interlocking arrangement of untreated logs or timber. Use at the base of a slope where a low wall may be required to stabilize the toe of the slope and reduce its steepness or where space is limited and a more vertical structure is required. It should be tilted back if the system is built on a smooth, evenly sloped surface.

Make live branch cuttings ½” to 2” in diameter and long enough to reach the back of the wooden crib structure. Build constructed crib of logs or timbers from 4” to 6” in diameter or width. The length will vary with the size of the crib structure. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability. Place the first course of logs or timbers at the front and back of the excavated foundation, approximately 4 to 5 feet apart and parallel to the slope contour. Place the next set of logs or timbers at right angles to the slope on top of the previous set. Place each set of timbers in the same manner and nail to the preceding set. Place live branch cuttings on each set to the top of the cribwall structure with growing tips oriented toward the slope face. Backfill the cribwall, compact the soil for good root-to-soil contact, then apply seed and mulch.

Vegetated Rock Gabions

Vegetated gabions combine layers of live branches and gabions (rectangular baskets filled with rock). This practice is appropriate at the base of a slope where a low wall is required to stabilize the toe of the slope and reduce its steepness. It is not designed to resist large, lateral earth stresses. Use where space is limited and a more vertical structure is required. Overall height, including the footing, should be less than 5 feet.

Make live branch cuttings from ½” to 1” in diameter and long enough to reach beyond the rock basket structure into the backfill. Starting at the lowest point of the slope, excavate loose material 2 to 3 feet below the ground elevation until a stable foundation is reached. Excavate the back of the stable foundation (closest to the slope) slightly deeper than the front to add stability and ensure rooting. Place the wire baskets in the bottom of the excavation and fill with rock. Backfill between and behind the wire baskets. Place live branch cuttings on the wire baskets at right angles to the slope with the growing tips oriented away from the slope and extending slightly beyond the gabions. Root ends must extend beyond the backs of the wire baskets into the fill material. Place soil over the cuttings and compact it. Repeat the construction sequence until the structure reaches the required height.

Joint Planting

Joint planting or vegetated riprap involves tamping live cuttings into soil between the joints or open spaces in rocks that have previously been placed on a slope. Use where rock riprap is required. Joint planting is used to remove soil moisture, to prevent soil from washing out below the rock and to increase slope stability over riprap alone.

Make live branch cuttings from ½" to 1½" in diameter and long enough to extend into soil below the rock surface. Remove side branches from cuttings leaving the bark intact. Tamp live branch cuttings into the openings of the rock during or after construction. The root ends should extend into the soil behind the riprap. Mechanical probes may be needed to create pilot holes for the live cuttings. Place cuttings at right angles to the slope with growing tips protruding from the finished face of the rock.

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Temporary Stream Crossing (TSC)

Photo courtesy of Steve Taylor, Auburn University Biosystems Engineering

Practice Description

A temporary stream crossing is a short term road crossing constructed over a stream for use by construction traffic to prevent turbidity and streambed disturbance caused by traffic. A temporary stream crossing can be a low water crossing, a culvert crossing, or a bridge with or without embankment approaches. Temporary stream crossings are applicable on construction sites where traffic must cross steams during construction.

Planning Considerations

A stream crossing can be an open ford, a pipe (culvert), or bridge crossing. Stream crossings can be a useful practice to provide a means for construction traffic to cross flowing streams without damaging the channel or banks or causing flooding, and to keep sediment generated by construction traffic out of the stream. Stream crossings are generally applicable to flowing streams with drainage areas less than 1 square mile. A qualified design professional should design permanent structures to handle flow from larger drainage areas.

Careful planning can minimize the need for stream crossings and the qualified design professional should always try to avoid crossing streams. Whenever possible, complete the development separately on each side and leave a natural buffer zone along the stream. Temporary stream crossings are a direct source of water pollution; they may create flooding and safety hazards; they can be expensive to construct; and they cause costly construction delays if damaged by flooding.

Temporary stream crossings are necessary to prevent construction vehicles from damaging streambanks and continually tracking sediment and other pollutants into the flow regime. However, these structures are also undesirable in that they could cause a channel constriction, which can cause flow backups or washouts during periods of high flow. For this reason, the temporary nature of stream crossings is stressed. They should be planned to be in service for the shortest practical period of time and to be removed as soon as their function is completed.

Fords made of stabilizing material such as rock are often used in steep areas subject to flash flooding, where normal flow is shallow (less than 3”) or intermittent. Fords should only be used where crossings are infrequent. Fords are especially adapted for crossing wide, shallow watercourses. Generally do not use fords where bank height exceeds 5 ft. Rock material used for the ford may be washed out during large storm events and require the rock to be replaced. Mud and other contaminants are brought into the stream on vehicles using ford crossings unless crossings are limited to no flow conditions.

The criteria contained in this practice pertains primarily to flow capacity and resistance to washout of the structure. From a safety and utility standpoint, the qualified design professional must also be sure that the structure is capable of withstanding the expected loads from heavy construction equipment. The qualified design professional must also be aware that such structures are subject to the rules and regulations of the U. S. Army Corps of Engineers for in-stream modifications (404 permits).

Design Criteria

Culvert Crossings or Spans (Bridges)

The structure should be large enough to convey the flow expected from a 2-year frequency, 24-hour duration storm without appreciably altering the stream flow characteristics. The structure may be a span or culvert. If culverts are used, see Table TSC-1 for aid in selecting the appropriate size. (Multiple culverts may be used in place of 1 large culvert if they have the equivalent capacity of the larger one). The minimum-sized culvert that may be used is 18”.

Where culverts are installed (Figure TSC-1), compacted soil will be used to form the crossing. The depth of soil cover over the culvert should be equal to ½ the diameter of the culvert or 24”, whichever is greater. To protect the sides of the fill from erosion, riprap shall be used and designed in accordance with the practice Outlet Protection.

The length of the culvert should be adequate to extend the full width of the crossing, including side slopes.

The grade of the culvert pipe should be at least 0.25” per foot.

Table TSC-1 Culvert Selection Guide (pipe, diameter, inches)

Drainage Area (Acres)	**Average Slope of Watershed**			
	1%	4%	8%	16%
1-25	30	30	36	36
26-50	30	36	42	48
51-100	36	48	48	54
101-150	42	48	60	60
151-200	42	54	72	72
201-250	48	60	72	72
251-300	48	60	72	72
301-350	48	60	72	2X60
351-400	54	72	2X60	2X60
401-450	54	72	2X60	2X60
451-500	54	72	2X60	2X72
501-550	60	72	2X60	2X72
551-600	60	72	2X60	2X72
601-640	60	72	2X60	2X72

Assumptions for determining USDA-NRCS Peak Discharge Method; CN=70; Rainfall depth (average for Alabama) = 4.3” for 2-year/24-hour storm; No tailwater exists; and the depth of water at the inlet invert is 1.5 X diameter.

The top of the compacted fill should be covered with 6” of Alabama Highway Department course aggregate No.1 stone (3/4” to 4”).

The approaches to the structure should consist of stone pads meeting the following specifications:

- Stone: Alabama Highway Department course aggregate No.1.
- Minimum thickness: 6”.
- Minimum width: equal to the width of the structure.
- Minimum approach lengths: 25 feet.

Culvert crossings and spans should be designed with features that will prevent damage, destruction or removal during major flood events (i.e. cabling, emergency bypass, etc.).

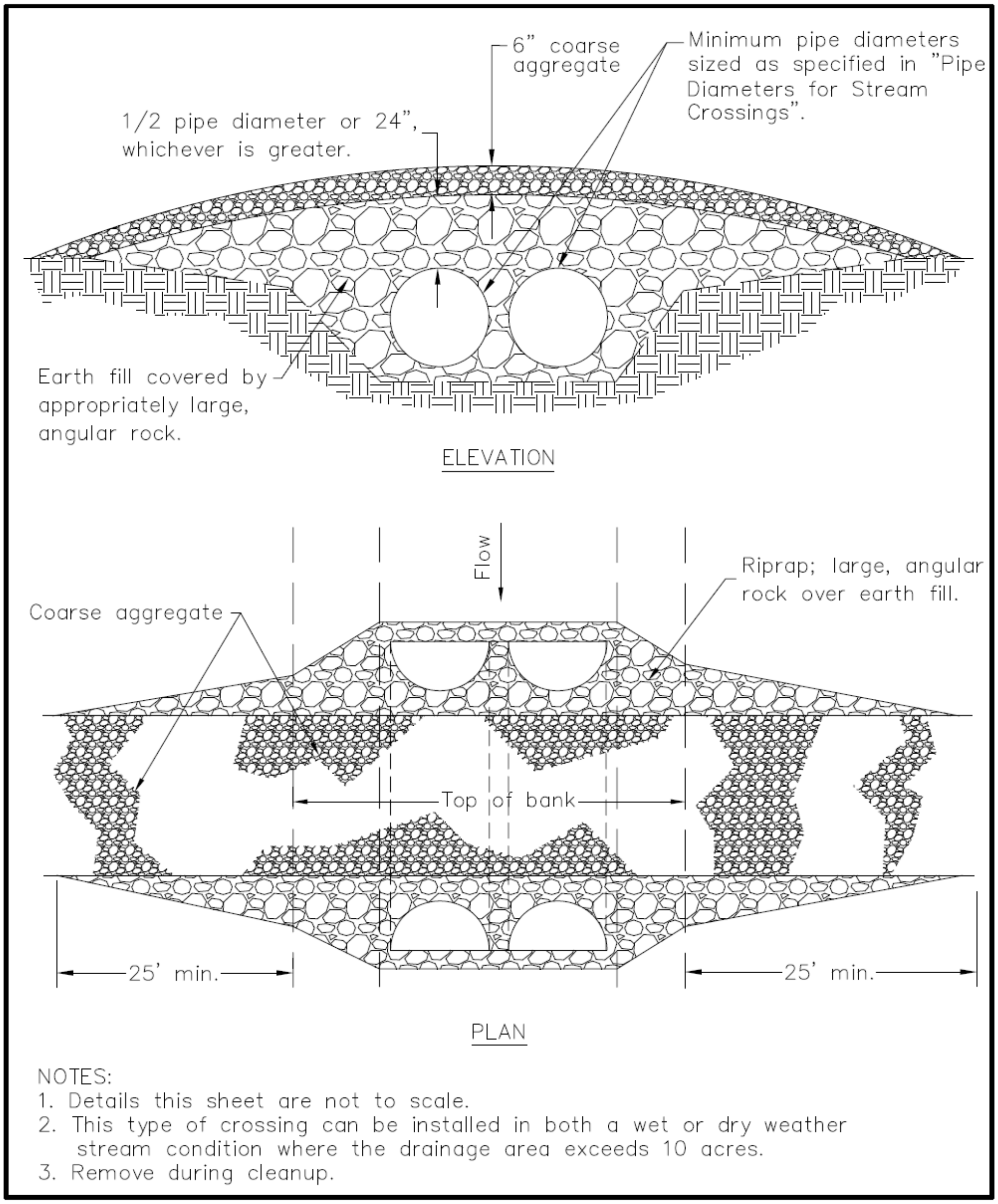

Figure TSC-1 Culvert Stream Crossing

Fords (See Figure TSC-2)

Stream banks should be excavated to provide approach sections of 5:1 or flatter.

The width of the ford crossings should be wide enough for the construction equipment to safely use.

Filter fabric material designed for use under riprap (see Channel Stabilization practice) should be installed on the excavated surface of the ford according to the manufacturer's recommendations. The fabric should extend across the bottom of the stream and at least 25 feet up each approach section. All edges of the fabric should be keyed in a minimum of 1 foot.

Alabama Highway Department course aggregate No.1 stone, 6" thick should be installed on the filter fabric and also should be used to fill the 1 foot keyed edges of the fabric.

The final surface of the stone in the bottom of the watercourse should be the same elevation as the watercourse bottom in order to eliminate any overfall and possible scour problems.

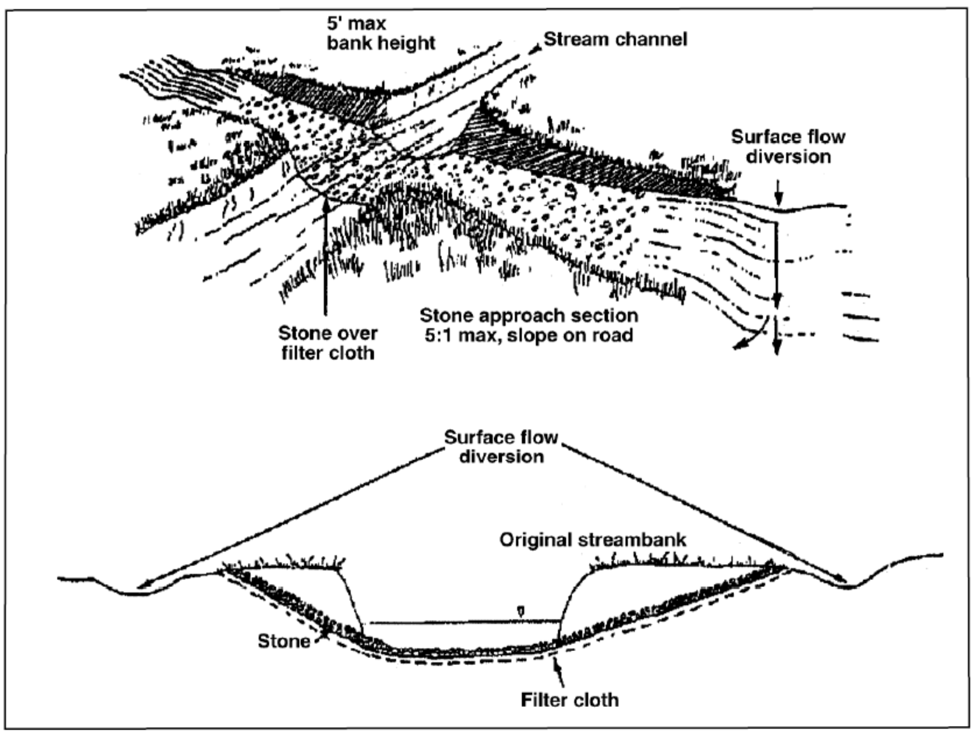

Figure TSC-2 Ford Stream Crossing